DISCUSSION ON THE ABOVE PAPER, AND TWO OTHER PAPERS* ON THE IONOSPHERIC ABSORPTION AND REFLECTION OF RADIO WAVES, BEFORE THE RADIO SECTION, 5TH MAY, 1954

Mr. G. Millington: Some work which was done at Great Baddow during the 1939–45 War is referred to in the paper by Tremellen and Cox.† It was afterwards discontinued, partly because the nearness of Great Baddow to Slough did not justify what was in effect a duplication of effort.

At the Kelvin Lecture‡ we gained a vivid impression of the ionosphere as a rushing torrent or at least as being disturbed by waves running through it with high velocities. It is at first sight surprising that under such conditions we get any coherent reflections, and the fading of the echoes is partly due to phase interference between scattered waves. I should like Mr. Piggott's assurance that when these effects are averaged out we really can relate the loss of amplitude in the reflected signal to actual absorption in the ionosphere, allowing, of course, for the divergence of the wave.

I am interested in the question of allowing for the earth's magnetic field. The usual correction given in eqn. (3) of Mr. Piggott's paper holds for the extraordinary wave only under very limited conditions at small angles to the direction of the earth's field. Under most conditions the extraordinary echo can be seen only on frequencies large compared with the gyro-frequency,

* PIGGOTT, W. R.: "The Reflection and Absorption of Radio Waves in the Ionosphere (see 1953, 100, Part III, p. 61).
BEYNON, W. J. G.: "Some Notes on the Absorption of Radio Waves reflected from the Ionosphere at Oblique Incidence" (see 1954, 101, Part III, p. 15).
† TREMELLEN, K. W., and COX, J. W.: "The Influence of Wave-Propagation on the planning of Short-Wave Communication," *Journal I.E.E.*, 1947, 94, Part IIIA, p. 200.
‡ RATCLIFFE, J. A.: "The Physics of the Ionosphere, 45th Kelvin Lecture," *Proceedings I.E.E.*, 1954, 101, Part I, p. 339.

and the correction is small and probably within the limits of experimental observation. It would surely therefore be better to omit it in order to avoid suggesting that it is valid where it does not in fact apply. With regard to eqn. (5), I am surprised that it is possible to represent the complicated expression for the specific absorption in terms of a modifying factor M and the refractive-index function $1/\mu - \mu$, where μ presumably is given by the Appleton–Hartree formula and not by the simple no-field value. Is this an approximate formula, or is it directly derived from magneto-ionic theory? As far as I know, it is impossible to effect such a simplification unless suitable approximations that are not obvious can be made.

With regard to Dr. Beynon's paper, it would be useful to have a simple diagram illustrating the important point concerning the correlation between the increased absorption and the reception of E-layer reflections at the appropriate distance nearer to the transmitter. Has Dr. Beynon considered the possible effect on the observed F-echo amplitude of a similar patch of E-layer ionization in the path of the downcoming wave?

Does this explanation of the failure of the cos i law suggest that this mechanism is nearly always operative, as I gather that, in general, the results are in agreement with the omission of the cos i factor? Incidentally it would be useful to have some indication of the theoretical argument supporting the omission of this factor, when the waves have to penetrate a thin layer, or at least a reference to a published proof of this proposition.

Mr. Allcock's paper raises the question of the polarization of the waves at oblique incidence, where it is not permissible to assume, as is often approximately true at vertical incidence, that the energy in an incident plane-polarized wave is equally shared between the ordinary and extraordinary waves on entry into the ionosphere. Did the author consider the possibility that under some conditions the characteristic polarization ellipses may be such that a wave from a vertical aerial may excite only a relatively small proportion of the ordinary mode?

I have made some calculations of absorption at oblique incidence for the ordinary wave, and all the results so far suggest that to a large extent an increased absorption of the upgoing wave is compensated by a decreased absorption of the downcoming wave, and vice versa, so that Martyn's theorem with the cos i factor should be nearly true. Here, of course, the theorem is interpreted, as in the similar equivalent path theorem, as comparing the oblique-incidence case with that at vertical incidence, both in the presence of the earth's magnetic field, since the measurements made at vertical incidence inevitably include the effect of the field. Have the authors any views on this?

Dr. R. L. Smith-Rose: One of the most important results of these papers will be to display to the radio-operating engineer, who is responsible for maintaining and looking after communication or broadcasting services, how difficult it is to satisfy the demand for knowledge of the absorption, attenuation or circuit loss which is likely to be suffered in operating any radio circuits. These papers make self-evident the various difficulties which are found in exploring the subject.

We are told, on theoretical grounds, that under certain conditions the absorption will vary as the cosine of the zenith angle of the sun raised to a certain power, n, but, as Mr. Allcock has demonstrated, n can vary over the range $0\cdot5$–$1\cdot5$. We may be able to correlate this value with a seasonal change, and there seems to be some indication of this, but it is not obvious what is the best value of n to use on any specific occasion.

Furthermore, when Martyn's theorem is used to translate the conditions from vertical to oblique incidence, Dr. Beynon demonstrates that much better agreement with observations is obtained if we omit the factor cos i.

These papers demonstrate that there is need for a great deal of further research on the subject, particularly if we are to take as our target the ability to supply the radio-operating engineer with some definite information, in tabular or graphical form, which will enable him to assess the total attenuation which he will experience in operating a circuit with a particular frequency over a particular distance and at a certain time and season. The type of approach adopted by Mr. Piggott, whereby we abstract a quantity called the A-factor, which, if the operating engineer can decide on the value of the gyro-frequency for the ionosphere, will enable him to assess the total absorption in the D-region, is a good start. If we can draw up other Tables, specifying what quantities should be taken into account in order that the absorption in the various portions of the ionosphere may be determined, the radio-operating engineer can then estimate what the line communication engineer knows as the "insertion loss," which is the information required. He can then decide how much power is needed at one end to establish a certain signal/noise ratio at the other.

Dr. J. W. Findlay: With regard to Figs. 8 and 9 in Mr. Piggott's paper, which deal with the agreement with the frequency law, this law, if true, can be used to decide whether a particular part or all of the absorption is of the non-deviative type. How easy is it to find such excellent agreement when one takes the whole of the absorption results into account?

An example of the difficulty in interpreting the results of absorption measurements is given in Fig. 7 of the paper by Mr. Allcock, which shows the variation of the index n in the power formula $\alpha = \beta \cos^n \chi$. This is a difficult determination to make, because the results are drived from in the form of log/log plots. This means that if there is any constant absorption present or if the equipment calibration is not correct—both being difficult to determine—the index n will be in error.

In the course of experiments which have been going on in Cambridge since May, 1951, we have been measuring both the daily and the seasonal variation of absorption on two frequencies at vertical incidence. The results at midday have been compared with those made at the Radio Research Station, and the agreement is excellent.

We have, however, attempted to discover whether there is one part of the absorption which is dependent on the sun's zenith angle and another part which is not so dependent and which may be called "sporadic." We have observed the annual variation of absorption and found that it is not unreasonable—although not very reasonable—to attempt to find a minimum absorption which exists on every particular day. This minimum absorption (which can be guessed at from the yearly curves) follows a regular law of variation with the sun's zenith angle. If we look for the difference between this minimum absorption on any day and the total absorption, and regard the difference as sporadic absorption, we find, as would be expected from the well-known results, that most of this sporadic absorption occurs in winter. It obeys the frequency law fairly closely in winter, so that we can say with some confidence that this excess absorption is occurring in the D-region, where the conditions are such that it would be expected that the frequency law would be obeyed. The minimum absorption seems to follow the same law throughout the day and the year, and it can be stated approximately as

$$\log \rho \propto (\cos \chi)^{0\cdot75}$$

Mr. G. O. Evans: I should like to refer to some further analyses carried out at the Post Office on the results of measurements of the angles of elevation of transatlantic signals made with the musa receiving system. The angles shown in Fig. 2 of Dr. Beynon's paper are, of course, monthly means, and we have

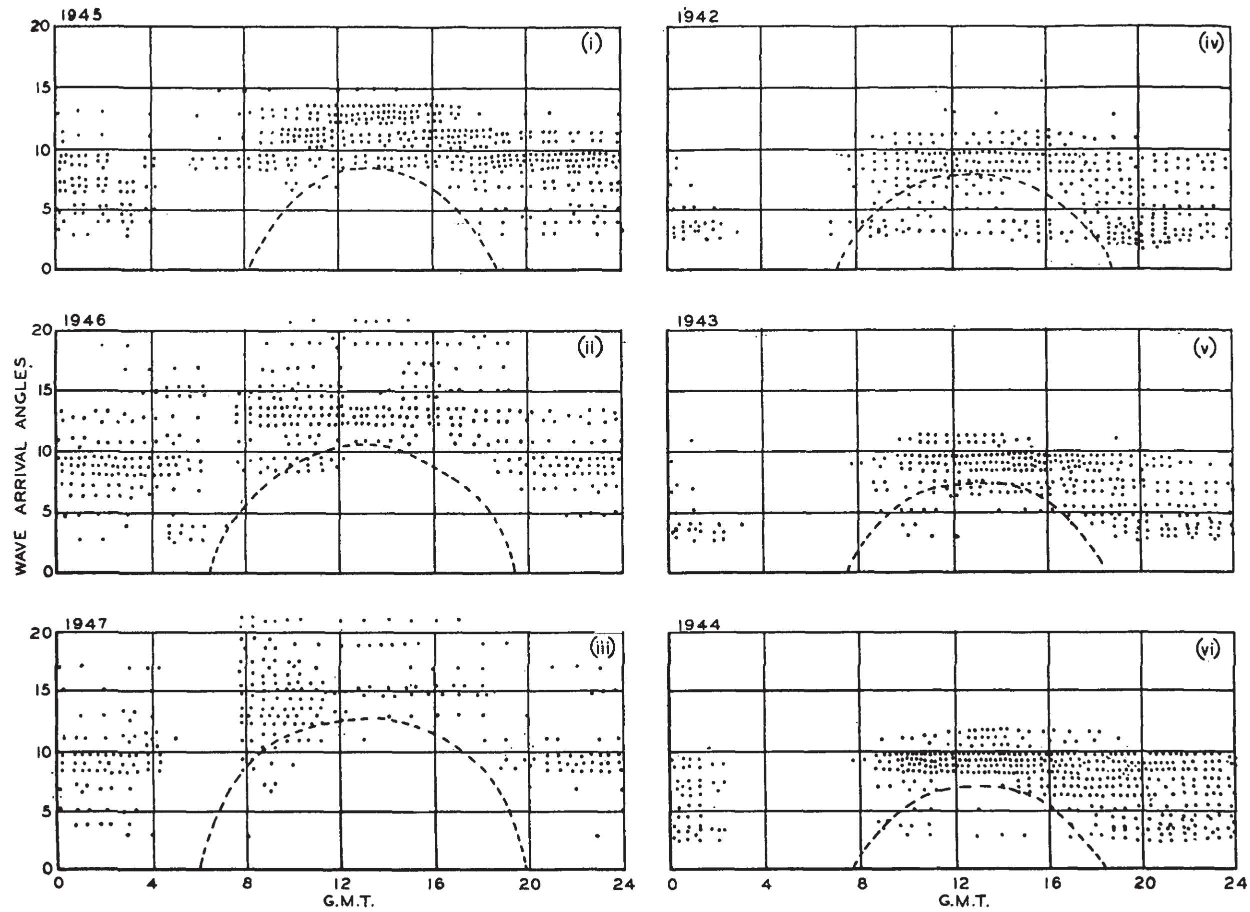

Fig. A

extended the analyses of these and similar measurements to examine the scatter about these mean values. Fig. A (i)–(iii) shows the results obtained for 14·59 Mc/s in July during three years approaching sunspot maximum. The Figures show the individual values of the angles of elevation recorded at hourly intervals throughout the month. The broken line shows the E-region penetration angle for 14·59 Mc/s which has been calculated from the Slough measurements of f_E, the curve being displaced by one hour to represent conditions at a point approximately 1 000 km west of Slough. It can be seen that practically all the angles recorded are above the penetration angle and that the changes in the mode of propagation at sunrise and sunset follow the variations of the E-region penetration angle very closely. These results support the view advanced by Dr. Beynon that the lower limit of the angle of elevation of trans-atlantic signals is set by deviative absorption in the E-region.

Fig. A (iv)–(vi) shows the corresponding results for three years approaching sunspot minimum, and it will be seen that in 1942 a considerable number of the angles recorded were below the penetration angle. A more detailed examination of the data showed that on 9 days during July, 1942, nearly all the angles recorded between approximately 1 100 and 1 500 hours G.M.T. were below the penetration angle. This suggests that on some days the E-region prevents signals reflected from the F-region reaching the receiver, those signals which are received being reflected from the E-region. The field strengths recorded under these conditions are, if anything, slightly greater than the average values for the month, and on occasion only one value of the angle of elevation is recorded, in contrast to the normal condition of two or three angles being present simultaneously.

An analysis of the results obtained for 14·59 Mc/s during July over the period 1942–50 showed that it was only in 1942 that there was marked evidence of angles of elevation below the E-region penetration angle, and that for the other frequencies used there was no significant evidence of this effect. An examination of the results for July, 1952, when the sunspot number was approximately the same as for July, 1942, showed that, for 14·59 Mc/s, angles of elevation below the E-region penetration angle were recorded on seven days. It therefore appears that under these conditions we get rather frequent reflections from the E-region. Under these particular conditions when the sunspot number is about 30 and the working frequency 14·59 Mc/s, is it possible for the E-region in summer to be particularly sensitive to small changes in ionization, so that while it normally causes deviative absorption, it can at times cause total reflection?

Mr. H. Stanesby: I am a little disturbed to learn from the papers that there are only two ionospheric observing stations in the world regularly making absorption measurements, and to see the big discrepancies between observed values of absorption and those computed from current theories. Nevertheless, the potential value of the work is very great.

I wonder whether we might persuade other countries to make observations of vertical-incidence absorption, so that we need not continue to carry the burden alone. Is it not possible that commercial users of the ether might, by closer co-operation with research workers, provide a great deal of information of scientific value? With guidance from, say, the D.S.I.R. they might make returns of the results obtained in operating commercial services which, when analysed and correlated with the results of more precise and scientific measurements, might yield results of considerable value.